

## **Coastal Mixing and Optics Moored Array**

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### **LONG-TERM GOAL**

Our long-term goal is to identify and understand the dominant vertical mixing processes influencing the evolution of the stratification over continental shelves.

### **OBJECTIVES**

We want to understand the dynamics of the surface and bottom boundary layers over continental shelves and how the boundary layers contribute to mixing and the evolution of the stratification. We are particularly interested in the relative contributions of local, one-dimensional mixing processes, such as wind forced mixing, cooling, and tidal mixing versus three-dimensional advective effects.

### **APPROACH**

An array of moorings were deployed at a mid-shelf location in the Mid-Atlantic Bight in August 1996 and recovered in June 1997 to span the destruction of the thermal stratification in fall and redevelopment of the stratification in spring. The moored array consisted of a heavily instrumented central site (70-m isobath) and three more lightly instrumented surrounding sites: about 10 km onshore (64-m isobath), about 12 km offshore (86-m isobath) and 15 km along-isobath toward the east. At each site currents, temperature and conductivity measurements spanned the water column. Additionally, the central site included meteorological measurements to estimate wind stress, surface heat flux and surface buoyancy flux, wave measurements, and a fanbeam ADCP to identify Langmuir circulation.

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## **WORK COMPLETED**

Post-calibration and initial processing of the data from over 80 instruments has been completed. Data return is excellent. A data report summarizing the moored observations is in preparation.

Comparisons have been made between moored ADCPs and VMCMs at the inshore, central and offshore sites to evaluate the relative accuracy of the moored current measurements. Comparisons have also been made between the moored conductivity measurements at the central site and shipboard anchor station CTD profiles in fall and spring to evaluate our moored conductivity measurements which are subject to fouling and drift. Surface wave data, including directional spectra, have been processed, quality controlled, and made available to other CMO investigators. Non-directional wave parameters have been compared with nearby NDBC wave buoy records.

The sonic anemometer system on the central mooring ran continuously during the entire deployment. This data has been successfully merged with the VAWR and wave data. Direct covariance fluxes have also been computed by combining the sonic velocity measurements with the motion package deployed by Mark Grossenbaugh. Initial comparisons between the bulk, inertial-dissipation, and direct covariance fluxes have been conducted to investigate whether the fluxes exhibit any wave-age dependence.

Surface analysis and flux fields from regional Numerical Weather Prediction models have been archived for the field observation period. We now have an archive of Eta and RUC model surface fields for the eastern seaboard available on CD-ROM and have completed intercomparisons and evaluation of these model fields with our buoy observations (Baumgartner and Anderson, 1998).

## **RESULTS**

A number of intriguing features were evident from preliminary evaluation of the data. The August 1996 - June 1997 deployment captured both the breakdown in fall and redevelopment in spring of the stratification. Thermal stratification was strong in August with near surface temperatures of 18-20°C and near-bottom temperatures of 8°C. The thermal stratification decreased in four abrupt steps from September through mid November associated with several storm events and westward (downwelling) alongshore currents. Regional gridded meteorology products from numerical weather prediction (NWP) models indicated that forcing of the ocean by major storm events (including a hurricane, several northeasters and a mid-latitude cyclone) had different spatial and temporal characteristics. Thermal stratification at the central site was weak from mid November through mid December due to strong winds and surface cooling. The water column restratified in mid December due to an intrusion of warm (up to 10°C), salty, slope water along the bottom, under the cold (4-6°C), fresh, shelf water. This intrusion, which was presumably an onshore displacement of the shelf-slope front, was about 20 m thick and persisted from mid December through March. Historical data from the Nantucket Lightship suggests this persistent onshore displacement of the shelf-slope front is anomalous. Thermal stratification began to redevelop in late April due to surface heating and increased steadily through early June.

Intercomparison and evaluation of the NCEP regional Numerical Weather Prediction model fields with our buoy observations indicates the Early Eta (EE) model is the most suitable for use in forcing regional ocean modeling in support of CMO. We have removed biases from the EE surface

analysis fields, combined them with the 14km NESDIS SST analysis and employed state of the art bulk formulae to generate a set of revised air-sea momentum, mass and heat flux maps for the 11 month observing period over the whole Mid-Atlantic Bight and surrounding regions. The flux map data set spatial and temporal resolution is 29km and 3 hr respectively and is available on a pair of CD-ROMs.

A quantitative comparison of direct covariance momentum flux measurements to bulk aerodynamic and inertial dissipation estimates indicates that both indirect methods underestimate the flux to developing seas. To account for wave-induced processes and yield improved flux estimates, modifications to the traditional flux parameterizations were explored. The most successful of these new parameterizations was a formulation based on data taken during the ONR's MBL experiment. This formulation was applied to the inertial-dissipation estimates taken during CMO and significantly improved the agreement between the inertial-dissipation and direct covariance fluxes. This work led to the completion of a Master's thesis by Michiko Martin, a student in the joint program.

## **IMPACT/APPLICATION**

The successful field effort has yielded the most comprehensive set of moored array data on the New England shelf for studying vertical mixing and more generally the shelf dynamics. It should provide a critical context for interpreting other measurements acquired during the Coastal Mixing and Optics field program.

## **TRANSITIONS**

none

## **RELATED PROJECTS**

We anticipate collaborations with many of the other PIs in CMO.

Bottom boundary layers - We have already exchanged some data with Trowbridge and Williams and plan to collaborate closely with them and Paul Hill in understanding the dynamics of the bottom boundary layer and its impact on the rest of the water column. In particular, in collaboration with Trowbridge and Chapman (separate ONR funding) we plan to examine whether there is a shutdown of the bottom stress as suggested in recent modeling work by Chapman and Lentz.

Optics - We have begun some preliminary collaboration with Dickey, Sosik, Boss, and others looking at the influence of strong forcing events (storms and hurricanes) on the optical properties of the water and have provided them with our data to aid in the interpretation of their measurements.

Surface Waves - We have initiated data exchange with Don Thompson (Johns Hopkins University) and anticipate combining wave-rider buoy data and SAR imagery to document wave conditions associated with hurricane Edouard.

Spatial variability - We anticipate collaborating with Barth and Kosro and with Gawarkiewicz and Pickart (Primer study) to determine the influence of spatial variability in our interpretation of the moored observations. As a first step we have provided the moored current and pressure data to aid in detiding the shipboard ADCP data.

Hurricane response - We plan to collaborate with the GLOBEC PIs (Irish, Brink, Beardsley) on an examination of the response to hurricane Edouard over the New England shelf and Georges Bank.

The timeseries of air-sea fluxes derived from the mooring data during the Fall and Spring CMO cruises is available to all PI's through the CMO web page. These data have already been incorporated in many presentations by various CMO PI's. The full record of air-sea fluxes has been provided to J. Dusenberry and A. Robinson for use in their CMO modeling efforts.

National Weather Prediction model validation: We have been exchanging results from our NWP validation effort with Stan Benjamin, NOAA/ERL Forecast Systems Laboratory, who is developing the Rapid Update Cycle (RUC) regional weather forecasting model for NCEP.

We continue to collaborate with the MBL PIs (Friehe, Farmer, Smith, Pinkel) in our efforts to incorporate wave-induced forcing in our modeling efforts.

## **REFERENCES**

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